WHAT IS CLAIMED IS:

1. A hydraulic regenerative braking system for a vehicle, the system comprising:

at least one hydraulic machine operable as a pump configured to be driven by energy received from at least one vehicle wheel when the vehicle is braking, thereby facilitating storage of vehicle braking energy, the at least one hydraulic machine being further operable as a motor configured to be driven by stored braking energy, thereby providing torque to at least one vehicle wheel;

a first accumulator configured to receive fluid from the at least one hydraulic machine, and to store the fluid under pressure, the first accumulator being further configured to provide pressurized fluid to the at least one hydraulic machine, thereby facilitating use of the hydraulic machine as a motor;

a second accumulator configured to store pressurized fluid and to provide a charge pressure to an inlet of the at least one hydraulic machine;

a variable ratio transformer in communication with the first and second accumulators and the at least one hydraulic machine, the transformer being operable to vary the pressure of the pressurized fluid provided to the at least one hydraulic machine, thereby facilitating variation in the torque provided to the at least one vehicle wheel, the transformer being further operable to vary the pressure of the fluid received by the first accumulator; and

a control module configured to receive inputs related to operation of the vehicle, and to control operation of the transformer, the inputs including an acceleration request and a braking request.

2. The system of claim 1, wherein the at least one hydraulic machine includes at least two hydraulic machines, each of the hydraulic machines being disposed on a driving shaft of the vehicle, proximate a corresponding vehicle wheel.

3. The system of claim 1, wherein the transformer includes:

a) a housing including a high pressure port for facilitating transfer of fluid between the first accumulator and the transformer, a low pressure port for

facilitating transfer of fluid between the second accumulator and the transformer, and at least one machine port for facilitating transfer of fluid between the transformer and a corresponding hydraulic machine,

b) a rotor, rotatably disposed within the housing,

c) a plurality of pistons attached to the rotor, each of the pistons including a shaft and a head,

d) a plurality of cylinders, each of the cylinders being configured to receive a corresponding piston, and having a cylinder axis non-parallel to a corresponding piston shaft,

e) a first plate configured to be rotatably driven by the rotor, and having a first surface configured to contact one end of each of the cylinders and to allow each of the contacting cylinder ends to slide relative to the first surface, the first plate including a plurality of apertures therethrough, at least some of the apertures being configured to facilitate fluid flow to and from the cylinders, and

f) a second plate having at least three plate ports therein, each of the plate ports being configured to cooperate with at least one aperture in the first plate and one housing port, thereby facilitating fluid flow between a housing port and at least one cylinder, the second plate being rotatable relative to the housing ports to modify the transformer pressure ratio.

4. The system of claim 3, wherein each piston shaft includes a generally spherical end, and each piston head is configured to cooperate with the generally spherical end of a corresponding piston shaft, thereby allowing the piston heads to pivot relative to corresponding piston shafts, and allowing each of the piston heads to maintain a generally axial orientation relative to a corresponding cylinder during each piston stoke, and thereby facilitating the use of more than one seal between each piston and an corresponding cylinder.

5. The system of claim 3, wherein the first plate includes a plate portion having the first surface thereon and a separate hub portion attachable to the plate portion, thereby allowing the first surface to receive a smooth finish prior to assembling the plate portion to the hub portion, thereby facilitating sealing between the first surface and the cylinders.

6. The system of claim 3, wherein the plate ports are configured to cooperate with corresponding apertures such that the projected area of the plate ports and portions of the apertures outside the plate ports is generally constant regardless of the position of the second plate relative to the first plate, thereby inhibiting changes in separation forces between the first and second plates.

7. The system of claim 3, wherein the plate ports are configured to facilitate positioning of the first plate relative to the second plate such that fluid passes through the transformer with no substantial pressure change.

8. The system of claim 3, wherein each of the plate ports is generally arcuate, and is disposed at a corresponding radius from a center of the plate, and wherein one of the plate ports is disposed at a larger radius than the other two port plates, thereby providing radial overlap between plate ports.

9. The system of claim 3, further comprising a retainer circumferentially disposed around the cylinders, thereby inhibiting outward movement of the cylinders when the rotor is rotating at a high speed.

10. The system of claim 3, wherein the rotor includes a plurality of shuttle valves each of the shuttle valves being configured to provide a fluid path between a corresponding pair of cylinders, thereby inhibiting pressure spikes as the fluid changes pressure in the transformer.

11. The system of claim 10, wherein each of the shuttle valves includes a shuttle piston configured to inhibit shuttle piston impact at the end of a stroke.

12. The system of claim 1, wherein each of the at least one hydraulic machines includes:

a housing, including a high pressure fluid port and a low pressure fluid port,

a plurality of radial pistons, each of the pistons being configured to reciprocate within a corresponding cylinder in the housing, thereby pumping fluid when the hydraulic machine is operating as a pump, and providing torque when the hydraulic machine is operating as a motor, each of the pistons including a corresponding cam follower,

a cam configured to cooperate with the cam followers to translate rotational motion of the cam into linear motion of the pistons when the hydraulic machine is operating as a pump, and to translate linear motion of the pistons into rotational motion of the cam when the hydraulic machine is operating as a motor, the cam including an aperture therethrough for receiving a rotatable shaft, and

a rotatable valve plate having a plurality of apertures therethrough, at least some of the apertures communicating with the high pressure fluid port and at least some of the apertures communicating with the low pressure fluid port, the valve plate being configured to provide a fluid path between the cylinders and the high pressure fluid port when corresponding pistons are in a power stroke and between the cylinders and the low pressure fluid port when corresponding pistons are in an exhaust stroke, thereby facilitating operation of the hydraulic machine as a motor, the valve plate being further configured to provide a fluid path between the cylinders and the high pressure fluid port when corresponding pistons are in an exhaust stroke and between the cylinders and the low pressure fluid port when corresponding pistons are in a power stroke, thereby facilitating operation of the hydraulic machine as a pump.

13. The system of claim 12, wherein the cam is disposed within the housing and includes a plurality of external lobes thereon.

14. The system of claim 12, wherein the housing includes first and second housing portions, and an outer ring, the first housing portion including the high and low pressure fluid ports, the second housing portion including the cylinders disposed therein, and the outer ring including a tapered bore to facilitate sealing of each of the cylinders.

15. The system of claim 12, wherein each of the at least one hydraulic machines further includes an axial piston connected to the valve plate with a link configured to translate linear motion of the axial piston into rotational motion of the valve plate, thereby facilitating indexing of the valve plate to switch operation of the hydraulic machine between a pump mode and a motor mode.

16. The system of claim 15, wherein each of the at least one hydraulic machines further includes a plurality of weights disposed within the housing and proximate the axial piston, the weights being configured to inhibit movement of the axial piston when the hydraulic machine is operating as a pump at a high speed, thereby indexing the valve plate to reduce the flow of fluid exiting the hydraulic machine.

17. The system of claim 1, wherein at least a portion of at least one of the accumulators includes a hydraformed chassis component.

18. A hydraulic machine operable as a pump configured to be driven by a rotating shaft, thereby increasing the pressure of fluid flowing through the pump, the hydraulic machine being further operable as a motor configured to be driven by pressurized fluid, thereby providing torque to a shaft, the hydraulic machine comprising:

a housing, including a high pressure fluid port and a low pressure fluid port;

a plurality of radial pistons, each of the pistons being configured to reciprocate within a corresponding cylinder in the housing, thereby pumping fluid when the hydraulic machine is operating as a pump, and providing torque when the hydraulic machine is operating as a motor, each of the pistons including a corresponding cam follower; and

a cam disposed within the housing, and having a plurality of external lobes configured to cooperate with the cam followers to translate rotational motion of the cam into linear motion of the pistons when the hydraulic machine is operating as a pump, and to translate linear motion of the pistons into rotational motion of the

cam when the hydraulic machine is operating as a motor, the cam including an aperture therethrough for receiving a rotatable shaft;

a rotatable valve plate having a plurality of apertures therethrough, at least some of the apertures communicating with the high pressure fluid port and at least some of the apertures communicating with the low pressure fluid port, the valve plate being configured to provide a fluid path between the cylinders and the high pressure fluid port when corresponding pistons are in a power stroke and between the cylinders and the low pressure fluid port when corresponding pistons are in an exhaust stroke, thereby facilitating operation of the hydraulic machine as a motor, the valve plate being further configured to provide a fluid path between the cylinders and the high pressure fluid port when corresponding pistons are in an exhaust stroke and between the cylinders and the low pressure fluid port when corresponding pistons are in a power stroke, thereby facilitating operation of the hydraulic machine as a pump.

19. A variable pressure ratio hydraulic transformer for modifying the pressure, flow rate, or a combination thereof, of fluid flowing through the transformer, the transformer comprising:

a housing having at least three housing ports, each of the housing ports being configured to operate as a fluid inlet or as a fluid outlet;

a rotor, rotatably disposed within the housing;

a plurality of pistons attached to the rotor, each of the pistons including a shaft having a generally spherical end, and a head configured to cooperate with the generally spherical end of the shaft, thereby allowing the head to pivot relative to the shaft;

a plurality of cylinders, each of the cylinders being configured to receive a corresponding piston, and having a cylinder axis non-parallel to a corresponding piston shaft;

a first plate configured to be rotatably driven by the rotor, and having a first surface configured to contact one end of each of the cylinders and to allow each of the contacting cylinder ends to slide relative to the first surface, the first plate including a plurality of apertures therethrough, at least some of the apertures being configured to facilitate fluid flow to and from the cylinders; and

a second plate having at least three plate ports therein, each of the plate ports being configured to cooperate with at least one aperture in the first plate and one housing port, thereby facilitating fluid flow between a housing port and at least one cylinder, the second plate being rotatable relative to the housing ports to modify the transformer pressure ratio.

20. A compact hydraulic machine operable as a pump and a motor, and configured to be disposed on a vehicle driving shaft proximate a vehicle wheel, the hydraulic machine comprising:

a housing, including a first housing portion, a second housing portion, and an outer ring, the first housing portion including a high pressure fluid port and a low pressure fluid port, the second housing portion including a plurality of radially oriented cylinders disposed therein, and the outer ring including a tapered bore to facilitate sealing of each of the cylinders;

a plurality of pistons, each of the pistons including a cam follower, and being configured to reciprocate within a corresponding cylinder;

a cam disposed within the housing, and having a plurality of external lobes configured to cooperate with the cam followers to translate rotational motion of the cam into linear motion of the pistons when the hydraulic machine is operating as a pump, and to translate linear motion of the pistons into rotational motion of the cam when the hydraulic machine is operating as a motor, the cam including an aperture therethrough for receiving a rotatable shaft; and

a rotatable valve plate having a plurality of apertures therethrough, and configured to selectively connect the cylinders with the low and high pressure fluid ports, thereby alternately facilitating operation of the hydraulic machine as a pump and a motor.

21. A method for operating a vehicle having a hydraulic regenerative braking system, the regenerative braking system including at least one hydraulic machine operable as a pump and a motor, and operable to receive energy from, and provide energy to, at least one vehicle wheel, first and second accumulators for storing and providing pressurized fluid, and a variable ratio transformer operable to vary the pressure of fluid provided to the at least one

hydraulic machine and to vary the pressure of fluid provided to the first accumulator, the method comprising:

operating the at least one hydraulic machine as a pump during a vehicle braking event, the at least one hydraulic machine being driven by energy received from the at least one vehicle wheel, thereby providing pressurized fluid to at least the first accumulator to store the pressurized fluid;

selectively operating the transformer to vary the pressure of the fluid provided to the first accumulator during the vehicle braking event;

operating the at least one hydraulic machine as a motor during a vehicle driving event, the at least one hydraulic machine being driven by pressurized fluid provided from at least the first accumulator, thereby providing torque to the at least one vehicle wheel; and

selectively operating the transformer to vary the pressure of the fluid provided to the at least one hydraulic machine during the vehicle driving event.